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FOOD SCIENCE AND NUTRITION

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The views expressed in this paper are those of the author and not necessarily those of the International Development Research Centre.

SUMMARY

Food science has delivered outstanding benefits to the people of economically developed countries. Their processed foods are protected from undesirable contamination and in general, North Americans have access to a greater variety of food choice and convenience than any nation in the world's industry.

Unfortunately, the poor in developing countries enjoy few of the benefits which food science had provided the more privileged. In most tropical countries losses between harvest or slaughter and eventual consumption are inestimable. Primitive systems of processing and the search for wood and water occupy many hours of the rural African woman's day.

The need for research to improve post-harvest food systems in developing countries demands the attention and ingenuity of many scientific disciplines and the greater support of all development agencies.

"La vie est une fonction chimique" wrote Antoine Lavoisier in 1780. Indeed all known and determinable biological processes in plants and animals, before and after death, depend upon the structural transformation of matter and the conversion of one form of energy to another through chemical reaction. Though food science and nutritional biochemistry, as discrete academic disciplines, are of comparatively recent origin, the knowledge upon which each is based and the techniques by which each is researched derive much from chemistry, not the least from Lavoisier's perceptive and systematic refutation of Becker and Stahl's ad hoc assumption that gave birth to the Phlogiston theory.

Alchemists before Becker leave evidence of more than a passing relation with food technology. Jean Dumas' remark that the early chemists borrowed their language from the kitchen is evidenced in such names as sugar of lead, butter of antimony, oil of vitriol and milk of lime; and by such laboratory techniques as washing and roasting. An Arabic manual of alchemy written in the 13th Century, includes among the descriptive properties of known substances the sensory qualities of colour, taste, smell and feel.

How much the alchemists learned of food chemistry, in their pursuit of the elixir is obscured, sometimes deliberately, by their paradoxes and their principle of dispersion: the use of maximum words to supply minimum information, a principle upheld by such philosophers as Maimonides who considered that in both theology and natural science there were topics that should not be fully explained. It is intriguing to speculate how much earlier in history food science might have been established had the alchemists been more rationally communicative, and more concerned with understanding and explaining natural biological phenomena than with seeking to transmute all matter to gold, and in pursuit of the Philosopher's stone and life's elixir.

Perhaps one should not be overly critical of the alchemists' objectives, bearing in mind the current penchant with transmuting edible carbohydrate to ethanol to feed automobiles; and the seeming obsession among food and health journalists with finding the perfect diet that will guarantee eternal life on this side of the grave. The latter seem unaware of George Bernard Shaw's dictum: "Do not try to live forever. You will not succeed." The former appear bent upon fulfilling Aldous Huxley's prophecy of a secular society whose chronology begins with the Year of Our Ford.

While the world's privileged minority appear most concerned with the rising cost and potential future shortage of petroleum products, for the world's poor majority, particularly their young, the most serious hazard is ill-health caused by malnutrition. While the former seek to live forever, the underprivileged struggle to find food sufficient to survive, walking many miles every day in search of wood with which to cook it.

Though for the poorest, malnutrition is a condition close to starvation, malnutrition in its broadest sense results from a diet inadequate to maintain physical and metal capacity and development.

Malnutrition imapirs the capacity for work output and lowers resistance to infection, which in turn increases the food nutrient demand to repair the damage wrought by disease. Malnutrition and chronic infection impair learning ability which further reduces the capacity for effective work. Consequently, malnutrition begins a vicious circle broken only by provision of an adequate diet.

It is impossible to determine the extent of malnutrition throughout the developing world, since gross statistical assessments of food production, combined with doubtfully reliable estimates of population, provide at best crude averages of available food per capita. These averages, themselves uncertain, provide little indication of the extreme variations that occur between years and seasons, among regions, among nations in a region, among communities within a nation, among families within a community, or even among members of the same family. Little that is precise and reliable is known of the nutritional losses between harvest and consumption, or of the many political, social and economic forces that constrain production, distribution and consumption of essential food supplies.

Relatively few countries appear to have created mechanisms by which to plan and monitor the production and fair distribution of essential nutrients. There is considerable evidence to indicate a significant correlation between income and diet; among the poorest both calorie intake and the quantity and quality of protein consumed decline in parallel with disposible income. In relatively few developing countries can one find detailed appraisals of seasonal variations in food availability or national policies that take account of the need for storage and distribution of essential foods from regions and seasons of abundance to those of scarcity.

In countries of the African Sahel, where 70 to 80% of energy is provided by cereals, seasonal variations in available food energy occur every year. During the months immediately before the harvest calorie deficiencies may reach 30% of requirement. In the drought years of the early 1970s, energy intake deficiencies of close to 50% were recorded. The survey data available illustrate the wide variability being evident among years, among seasons, among communities, among age groups and between settled and nomadic lifestyles. Even when, among the rural poor, calorie intake is sufficient the diet of many young children is nutritionally unsatisfactory, largely because the protein content and amino acid composition of the locally grown cereals, whatever the quantity ingested, are inadequate to satisfy a child's needs.

In the mid-1930s the League of Nations Committee on Nutrition wrote in its Report[1]: "The movement towards better nutrition in the past has been largely the result of the unconscious and instinctive groping of men for a better and more abundant life. What is now required is the conscious direction towards better nutrition. Such direction constitutes policy. Nutrition policy....must be directed towards two mutually dependent aims: first, consumption, bringing essential foods within reach of all sections of the (world) community; second, supply." The report then lists several courses of action necessary to insure an adequate consumption and supply, including: the recognition of nutritional policy as of primary national importance; better education on human nutrition; and a more equitable distribution of income since it is "the poorest people who are the most nutritionally deprived.

Forty years later, in 1977, the published report of the World Food and Nutrition Study[2] by the National Research Council of the United States states: "An important cause of malnutrition is the absence of policies and programs to foster the best use of available food supplies. ....In poor and rich countries alike, governments continually make decisions that affect nutritional status with little or no knowledge of the nutritional consequences. Success in alleviating hunger and malnutrition will depend upon increasing the supply of the right kind of food, reducing poverty, improving the stability of food supplies, and decreasing the rate of population growth." Thus a Committee composed of eminent scientists repeated the recommendation which an equally distinguished committee prescribed 40 years earlier. _Plus ça change; plus c'est la même chose!_

The Brandt Commission[3] reports that: "Eight hundred millions are estimated to be destitute in the Third World today." From statistics cited by FAO[4], the International Food Policy Research Institute (IFPRI)[5], and other generally reliable sources, between 1976 and 1980 world cereal production appeared to increase by about 5% while world population expanded by 9.5%. Over the same four year period, cereal imports into all developing countries increased by 66% and in the lowest income countries the proportion of cereal imports provided under food aid programs decreased by more than 30%. During the same period cereal stocks, expressed as a proportion of total world cereal consumption, decreased by 22%; the forecast world cereal stock for 1981 being roughly the same as the world stock held in 1974, the year when the World Food Congress was convened to emphasize an impending world food crisis.

For the next decade and beyond, prospects for a minimally adequate diet among the world's poorest people appear grim indeed. The lowest income food deficient nations, which represent almost two-thirds of the total population of developing countries, showed a food deficit equivalent to about 12 million tonnes of cereals in 1975. In these same low income countries it is forecast that by 1990 the food grain deficit may be six to seven times that of 1975.

Broadly speaking, the food available to any population can be increased by:

1. higher levels of productivity per unit of land;
2. the expansion of land under cultivation; and
3. greater efficiency in food conservation and distribution.

Research at the International Agricultural Research Centres (IARCs)[6] demonstrates how high-yielding cultivars of wheat and rice can increase cereal grain production in developing countries. The benefits to be derived from higher yielding food crop types and the improved agronomic systems by which they are sustained are far from being exhausted. It now requires that greater attention be given to the quality of edible grains of high-yielding cereals and to the total impact upon nutritional adequacy of changing agricultural patterns.

The benefit of legumes in the diet was known to the writers of books of Daniel and Ezekiel. Daniel is reported as having said: "Prove thy servants I beseech thee ten days; and let them give us pulse to eat and water to drink then let our countenances be looked upon before Thee and the countenances of the children that eat of the portion of the King's meat... At the end of ten days their countenances appeared fairer and fatter in flesh than all the children which did eat the portion of the King's meat."

The nutritional composition of all cereal proteins falls short of the standard reference pattern recommended by the FAO/WHO Expert Committee in 1975, cereal proteins, in varying degrees, being deficient in the essential amino acid lysine.

The protein in food legumes is nutritionally complementary to that of cereal grains, a combination of roughly two parts by weight of cereal with one part by weight of dried food legume (pulse) providing a combined amino acid composition of close to what is nutritionally desirable. Probably because of their low yields relative to wheat and rice, the area given to food legume cultivation in Asia has fallen significantly over the last two decades and, rather than the nutritionally desirable ratio of two tonnes of cereal for every tonne of legume, the Asian legume harvest approximates only one-tenth that of cereal production.[7]

In India, where rice and wheat production have increased dramatically over the past two decades, the harvest of food legumes and oilseeds appears to be declining. The 1979-80 Indian legume harvest was 4 million tonnes below that of 1978-79 and 2 million tonnes lower than the average for any year since 1951. Production of oilseeds, which provide edible vegetable oils and protein nutritionally complementary to cereals is grossly inadequate to meet the needs of many developing countries. While the poorest countries expend millions of dollars to import oilseeds and vegetable oils, some of the more affluent seek to substitute vegetable oils for mineral oils as engine lubricants.

The area of land under cultivation may well prove to be the most critical factor that determines the number of people who can be fed in the years ahead. During 1975 an average of approximately three people in developing countries were fed from each hectare of crop land. By extrapolation of an estimated population increase of 3% per year, during 1985 each hectare cultivated in 1975 will need to support four people; by the end of the century it will provide for close to six people. These crude averages do not reveal dramatic differences among different developing countries.

Table 1 illustrates the justification for cautious optimism in some instances, and near despair in others. In 1975, 60 million Mexicans were supported by 28 million hectares of arable land, equivalent to about two persons per hectare. In the same year, 37 million Egyptians depended upon 3 million arable hectares, equivalent to 13 people per hectare. It is estimated that by 1985 each arable hectare will need to support 3 Mexicans or 16 Egyptians and that by 2000 AD it will increase to 5 Mexicans and 22 Egyptians per arable hectare. The International Development Research Centre (IDRC) is cooperating with several universities and government agencies in an attempt to reclaim areas of the Egyptian desert for future agricultural production. Even with irrigation from the Aswan dam it is difficult to reclaim cultivable land at a rate equivalent to the loss caused by the spread of Cairo.

The depredation of arable land by urban sprawl is by no means confined to Egypt and other developing countries. The production of food surplus to national requirement can be expected to decline in those countries of North America and Europe whose governments persist in assigning higher priority to industrial growth than to agricultural production; who permit large areas of their best arable land to be devastated by urban growth, by the proliferation of highways and industrial complexes. The world over, conservation of arable land, of inland coastal waters and natural forests, seems to take second place to urban and industrial development.

In Canada for example, between 1971 and 1976 irretrievable losses of prime agricultural land to urbanization amounted to more than 38,000 hectares, most in the fertile and climatically favoured areas of the Montreal triangle, southern Ontario and the Fraser River Valley of British Columbia. In the United States, the U.S. Department of Agriculture calculated that 2.5 million hectares of prime crop land were converted to urban and related uses between 1967 and 1975, and from Europe similarly dismal statistics of urban sprawl across prime class agricutural land are reported.

In no area of human endeavour are technical efficiency, social and economic benefit more sharply contrasted between rich and poor nations than in the post-harvest food sector, the sequence that begins with harvest or slaughter and ends when the foos is eaten. It is to the efficiency of post-harvest systems that food and nutritional sciences have contributed so much in developed countires and so little in the less developed.

For North Americans, food science which combines the skills and knowledge of chemists, physicists, microbiologists, nutritional biochemists, engineers and many other professions, provide the most varied range of wholesome diets in the history of mankind. From the largest grocery stores, North Americans can choose several thousand different food items at all times of the year. Whereas the poorest of the world's people spend most of their income on food, less than 20% of the disposible income of Canadians goes to feeding themselves.

In contrast to electronics and chemical technologies, the traditional technologies of food preservation and transformation long preceded any scientific understanding of their consequences. Peking man probably ground grains and crushed berries and he certainly cooked his food. Alcoholic and panary fermentation were common around the Mediterranean more than 6,000 years ago long before Buchner and Emil Fischer laid the basis for enzymology and Pasteur, seeking the cause of a disease in silk worms, gave microbiology its origins. Seneca described how the Romans preserved shellfish and other perishable foods in packed snow from the mountains. Termites used evaporative cooling to air-condition their dwellings thousands of years before Joule and Kelvin explained the principle on which so much of modern food preservation depends.

Historically, food science has been primarily devoted to an understanding of:

(1) the biochemical and biohysical nature and composition of foods;

(2) the changes they undergo post-harvest; and

(3) the changes during such traditional technological transformations as fermentation, milling, drying, frying, baking, boiling and other forms of cooking.

What has been learned would fill many volumes and it would be idle to attempt even a cursory review in an article of these dimensions. The picture is however far from complete and will probably remain incomplete for many decades to come.

The biological raw materials of the food scientist are more highly and uncontrollably variable than most of those used by inorganic chemists. The properties and composition of the seeds and fruits of cultivated plants are influenced by genetic background, the environmental conditions of soil and climate under which they are grown, the methods by which they are harvested, stored and processed. At all stages following harvest, during and after processing, changes take place, involving so many diverse and complex chemical reactions, that it is virtually impossible to follow any one in isolation from the rest. Consequently the extensive body of knowledge acquired has resulted from both biochemical and biophysical measurement and from empirical observation. The microscopist can follow changes in starch properties that occur from the time bread leaves the oven.

It has long been known that the process of staling, manifested in an increased firmness in the crumb, can be accelerated by storage at temperatures close to $0^{o}C$ and retarded by storage at much lower temperatures. A precise scientific explanation of the staling phenomenon has however yet to be recorded.

In his 1962 message to Congress, President Kennedy listed four basic rights to which consumers are entitled. These include: the rights to safety; to be informed; to choose from a wide variety of products; and to make their concerns known to those who provide their essential goods and services.

One of the greatest contributions of chemistry and microbiology to society has been in protecting consumers against the natural, accidental, or intentional contamination of foods with toxins, anti- and non-nutrients. Pliny reported the adulteration of Roman bread and wine and the skill of the Greek Canthare in the art of adulteration gave rise to the expression "as artificial as Canthare". Though the adulteration of wine, beer, bread and spices occurred from the time they first became articles of commerce, food adulteration was not a matter of widespread concern until the time of the industrial revolution when large populations moved from subsistence agriculture to urban industry and came to rely upon foods produced and processed by others. Many of the adulterations of the industrial revolution, including the addition of alum to bread and copper and other metallic salts to improve food colour, probably arose as much from a desire to improve the food's appearance as from intent to cheat the consumer.

Because of the pioneering work of Dr. Hassall in Britain which led in 1860 to the world's first Food and Drugs Act, the reports by Pasteur to the Board of Hygiene and Sanitation in Paris, and subsequently to the professional competence and vigilance of many food protection agencies, hazardous, deliberate adulteration is not common in most developed food economies. Government agencies and food industries invest heavily and employ advanced analytical techniques to ensure that all foods marketed are safe and wholesome.

Given the growing predilection for "natural" foods, particularly those of plant origin, the innocent might conclude that most plants as harvested are composed entirely of wholesome nutrients. Such is not the case and many food plants, including those widely accepted, contain substances unsuitable for ingestion. Some, such as the mycotoxins result from infection of grains in the natural environment; others are synthesized by various plants. In its natural habitat the primary purpose of the plant is to survive and reproduce itself. One of the conditions of survival is protection against attack by predators and the defensive mechanisms in some plants includes the synthesis of substances toxic to human and other predatory animals.

Primitive people, probably by trial and error, found simple ways to eliminate, or reduce to relatively safe levels, naturally occurring toxins and nutritional inhibitors present in their staple food sources. Typical are the methods of water elution, fermentation and drying used by Amerindians to remove cyanogenic glucosides from cassava roots and the saponins present in Chenopods, other seeds and some potato genotypes. The decreased protein digestibility caused by the polyphenolic tannins present in the outer layers of some sorghum grains is probably offset by traditional methods of soaking in water or by alkali treatment by wood ash before grinding and cooking.[8] In scientifically controlled food systems, the food chemist and plant breeder cooperate in the elimination of antinutrients by genetic selection and/or processing.

Judging by the space it is allotted in the popular press, nutrition is a subject of lively interest among North Americans. Not surprising, in a society that enjoys greater logevity than most others, greatest interest is focussed upon nutrition in relation to the maladies most common among older people. Cholesterol and cardiovascular disease are subjects almost as popular among North American journalists as crime and moral delinquency.

Though the chemist can analyze the relative composition and levels of concentration of most known nutrients, chemistry alone cannot determine nutritional adequacy. The adverse effects of grossly excessive or inadequate nutrient intakes are often demonstrable, but what constitutes an ideal diet for any condition of man, woman or child is far from certain. Recommended daily allowances of known essential nutrients have changed over the years and are still not uniform among all countries. Not all nutritionists agree that the world protein problem, much discussed a decade ago, has entirely disappeared.

What forms of carbohydrate and lipid provide the most satisfactory source of human energy is still debated and the possible association between fatty acid composition and cardiovascular disease intrigues many professional and amateur nutritionists. Some now suggest that diets low in all forms of lipid are preferable and that energy is more desirably derived from complex polysaccharides than from either lipids or simple sugars. In spite of the fact that, 2000 years ago Hippocrates recommended unbolted wheat bread for its salutary effects of the bowel, for many centuries most bread eaters preferred low extraction, light coloured wheat flour over dark bread made from whole grains. Now it is widely advocated that the higher lignocellulosic fibre content of long extraction wheat flours may be beneficial to gastrointestinal function.[9] How much and what form of dietary fibre is best suited to all conditions of people is still far from certain.

It is difficult if not impossible to determine quantitatively and precisely human requirements for any of the known essential nutrients. In domestic and farm animals nutritional balance can be determined according to such desirable characters as rate of weight gain and carcass composition. Nutritional requirements for human health cannot be so easily prescribed since they involve such complex criteria as resistance to infection, healthy longevity, physical fitness and intellectual capacity, no one of which is very easily quantified.

Nutritional studies with human subjects are expensive and time consuming; humanitarian and ethical considerations restrict the range of variables that may be studied, the techniques of assessment that can be used, and the period of time over which any experiment may be continued. Consequently, recommended daily allowances of all dietary standards are the results of professional judgements based on the best available evidence.

The nutritional well being, particularly of the innocent and gullible, might be better served if the popular press reported less dramatically and remembered with Alexander Pope that: "A little learning is a dangerous thing....and shallow draughts intoxicate the brain".

The contribution made by food science to convenience in the kitchen is evident to anyone who walks through a North American grocery store. As much, if not more, than any other branch of learning, food science has made it possible for both parents in a household to pursue their careers without detriment to the adequacy or variety of their family's diet. The provision of variety and convenience for the world's privileged minority will no doubt challenge the ingenuity of food scientists for years to come. Many others will continue to seek a more fundamental and comprehensive understanding of the deteriorative changes that take place post-harvest and post-slaughter.

In addition, significant economies in energy consumption by the food industires must be achieved if food processing and distribution costs are to be controlled. Of the total energy consumed in the North American food chain, roughly 18% is absorbed by agricultural production, 32% by processing and packaging, 20% by transportation and distribution, and roughly 30% in domestic storage and food preparation.[10] Given present incentives, there is little doubt that greater efficiency of energy use can be realized without detriment to the nutritional quality or forms of convenience in which processed foods are supplied.

Evidentally, and the clamour of its detractors notwithstanding, food science has made an immense contribution to the physiological, economic and social well being of people living in the world's wealthier countries. Such is not the case among the poor rural people of Africa, Asia, Latin America and the Middle East, where post-harvest nutrient losses are high and food distribution is uneven in consequence of many ill-defined economic, social, political, logistic and technological causes.

Two adverse influences appear persistent and pervasive. First is an apparent reluctance to study and comprehend post-harvest systems as they exist and to diagnose inadequacies before prescribing palliatives. The second, related to the first, results from an unwarranted optimism in the transferrability of technology. To those who advocate the transfer of appropriate technology one might ask "appropriate to whom - to those who seek to transfer or those who are to receive?".

Scientific principles are universally transferrable; many technologies are not. Technologies based upon biological principles, whether they relate to the cultivation of edible plants or to the transformation, preservation and distribution of plant and animal products, are intensely influenced by their surrounding physical, social and economic environments. Consequently, it is inevitably difficult, and frequently impossible to transfer post-production (post-harvest) technologies and food processing systems, between countries with temperate climates and access to advanced technological control, and less privileged communities of the semi-arid and humid tropics. Post-production systems need to be studied comprehensively and in their entirety before change is proposed.[11,12] New or improved post-harvest technologies, based upon sound scientific principles, are best developed where they are to be used, in close cooperation with those who are to use and benefit from them. What is good for North Americans is not necessarily good for North, West, East or Southern Africans, particularly those living in poor rural communities.

To provide what is appropriate to need and to the capacity to use requires a change in political attitude among many who dictate the policies of bilateral assistance and those responsible for the training of future scientists in developing countries. The need for a comprehensive understanding of scientific principles is unquestionable. But in addition, food scientists and administrators need a broader comprehension of systems methodologies in order that each technological change will be effectively integrated into the system in which it is to function.

Though opportunities for the simple transfer of food technologies between rich and poor nations may be limited, the many opportunities for cooperation among scientists of all nations remain largely unrealized. More encouragement for sympathetic, sensitive, cooperative research between scientists in developed and less developed countries is essential if the future adequacy of the world's food supply is to be insured.

To this end, the International Council of Scientific Unions (ICSU) has created a Commission for the Application of Science to Agriculture, Forestry and Aquaculture (CASAFA) to stimulate cooperation in relevant research among the national academies and international scientific unions which constitute ICSU's membership. Several countries are in the process of establishing national CASAFA Committees and it is hoped eventually that most countries will do so. The participation of many disciplines is needed including several not commonly associated with food and agriculture. Also, the Government of Canada recently created a Cooperative Program, administered by the International Development Research Centre (IDRC), the purpose of which is to employ Canadian scientific resources for the benefit of less developed nations.

Though a nutritionally adequate diet for all mankind over the next two decades is far from being assured, universal food sufficiency can be realized if politicians, policy makers and the world's community of scientists accept the dictum of one of FAO's most enlightened directors, Dr. B.R. Sen: "One man's hunger is every man's hunger; one man's need is every man's need."

TABLE 1 (a). POPULATION PER ARABLE HECTARE IN SELECTED COUNTRIES, 1975.

	1975 ARABLE HECTARE (MILLIONS)	1975 POPULATION (MILLIONS)	1975 PERSONS PER ARABLE HECTARE	1965-75 AVERAGE ANNUAL RATE OF NATURAL INCREASE
MEXICO	28	60	2	3.5%
SOUTH KOREA	2.4	34	14	2.0%
INDIA	167	608	4	2.0%
CHINA	129	823	6	1.7%
KENYA	1.8	13	7	3.3%
TANZANIA	6.1	15	2	2.8%
EGYPT	2.9	37	13	2.3%
ALL LDCs	670	1900	3	2.5%

(NOTE TO EDITORS OF SCIENCE - PLEASE HAVE TABLE 1 (b) APPEAR IMMEDIATELY BELOW THIS TABLE)

TABLE 1 (b). PROJECTED POPULATION PER ARABLE HECTARE IN SELECTED COUNTRIES, 1985 AND 2000 A.D.

	1985 POPULATION (MILLIONS)	1985 PERSONS PER ARABLE HECTARE	2000 A.D. POPULATION (MILLIONS)	2000 A.D. PERSONS PER ARABLE HECTARE
MEXICO	85	3	136	5
SOUTH KOREA	41	17	54	22
INDIA	741	5	983	6
CHINA	974	7.5	1241	10
KENYA	18	10	28	15
TANZANIA	20	3.5	30	5
EGYPT	46	16	63	22
ALL LDCs	2400	3.5	3343	5

SOURCES FOR TABLES 1 (a) and (b):

Arable hectares from <u>FAO Production Yearbook 1976</u>. Arable hectares includes land used for both annual and permanent crops.

Population levels and rate of natural increase from <u>World Population Growth and Response</u>. 1976. Population Reference Bureau, Washington, D.C.

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